Abstract: Properties of columnar magnetic cobalt structures

The fabrication of metallic nanostructures with tailored geometry and material is one of the central challenges of nanotechnology because geometrical and material parameters are responsible for the optical, electrical, mechanical, chemical, or magnetic properties of such structures. The main aim of the PhD thesis was to determine the structural, magnetic and magnetoresistance properties of cobalt sculptured thin films (STF) deposited by glancing angle deposition (GLAD). Films obtained with this method are characterized by a strong magnetic anisotropy.

The deposition process was carried out in an ultra-high vacuum (UHV) chamber. The substrate was first held at an angle of 80° with respect to the surface normal, what resulted in formation of Co nanocolumns tilted towards the deposition source. Next, by rotating the substrate around the axis perpendicular to the sample plane for 180° at fixed time intervals, a stack of columns with alternating directions was formed (arms of zigzag structures).

The scanning electron microscopy (SEM) cross-sectional images of STF proved the existence of nanostructures such as: inclined and vertical columns and zigzags with different numbers of arms and segments. Measurements of surface topography performed using atomic force microscopy (AFM) indicated high roughness of the layers around 10 nm.

It is known that the angular variations of the coercive field H_C and the remanent to saturation magnetization ratio M_R/M_S can provide information about the magnetization reversal processes. Therefore, in order to determine the dominant magnetization reversal process and the direction of the hard axis of magnetization in STF of different thicknesses and shapes the measurements with alternating gradient magnetometer (AGM) were performed. The angular dependencies of H_C and M_R/M_S were extracted from the hysteresis loops. The fact that the shape of the coercivity curve did not follow the shape of M_R/M_S curve indicated the curling magnetization reversal mode, described by theoretical approach of Frei and Aharoni. In the other cases the dominant process was coherent magnetization, characterized by Stoner-Wolfarth model.

For the first time, it was possible to observe the coexistence of coherent rotation

and curling mode and the dominant role of the curling mode in this type of STF. The coherent magnetization reversal process is dominant for the 10 nm thick Co pseudo-continuous layer (deposited at an angle of 80° with respect to the surface normal). An angular dependent transition from coherent rotation to curling magnetization reversal mode was observed for thin Co films, which consisting of titled columns, each 20, 30, 50 and 250 nm high. The coherent magnetization process was observed for small range of angles near the direction of hard magnetization axis.

A superposition of two the loops with different H_C values, which indicated the presence of two different magnetic species, were observed for the STF consisting of zigzag-type structures of four and six arms, each 60 nm high. One of the loops, with larger H_C value, was assigned to origin from the zigzag nanostructures. The second loop, with smaller H_C value, was assigned to origin from the magnetization of a pseudo-continuous Co layer. The curling magnetization reversal mode was the dominant process for Co STF consisting of zigzag structures.

The amplitude of the angular dependence of magnetoresistance was defined. The maximum value of magnetoresistance amplitude for STFs consisting of nanocolumns and zigzag structures was equal to 0.90% and 0.59%, respectively.

It is important to note, that the STF consisting of zigzag nanostructures exhibited very high maximum coercivity values (approx. 4 kOe), which are much higher than vertical cobalt columns of similar size (approx. 1 kOe) and pseudo-continuous cobalt layer (approx. 0.02 kOe). This could have significant meaning when thinking about potential applications of such structures, e.g. as pseudo-spin-valves in magnetic field sensors.